A comparison of measures of abundance of reptiles in Kwongan vegetation of the South-West of Australia, determined through systematic searching and pitfall trapping.

M.J. Bamford[1,2] & M.C. Calver[2]

[1] Bamford Consulting Ecologists. 23 Plover Way, Kingsley, Western Australia, 6026

bamford.consulting@iinet.net.au

[2] School of Veterinary and Life Sciences, Murdoch University, Murdoch, Western Australia 6150

m.calver@murdoch.edu.au

Correspondence to M J Bamford

ABSTRACT

Fauna surveys to determine the species richness, relative abundance and community structure of reptile assemblages are often important first steps in their conservation. Several sampling techniques are commonly used. Most involve trapping and assume a simple relationship between the absolute abundance of a species and the index of abundance obtained by sampling. However, comparing the effectiveness of different trapping techniques reveals biases among techniques. Therefore, without knowing absolute abundance, bias in a trapping technique can only be determined relative to other, biased techniques. To investigate this issue, measures of absolute abundance of reptiles were obtained by intensively searching measured quadrats (total removal plots), usually 5 m by 5 m, in two areas, with results compared with those obtained from pitfall trapping in one of these areas. Pitfall trapping was extremely biased towards large, surface-active lizards compared with the reptile assemblage determined by total removal, which was numerically dominated by small, fossorial species. Trapping data are influenced by the morphology and life history of a reptile species compared with results from total removal plots. Therefore, searching may provide a baseline for interpreting abundance data from trapping techniques, and for studies of population dynamics critical to assessing a population's robustness and its response to impacts.

Key words: Trapping rates, skinks, pygopodids, geckoes, micro-habitat

DOI: http://dx.doi.org/10.7882/AZ.2015.017

Introduction

Pitfall traps (hereafter referred to as pitfalls), and other trapping techniques such as funnel traps, are widely used to sample reptiles (Enge 2001, McDiarmid *et al.* 2012, Bamford *et al.* 2013) and are recommended in surveys for environmental impact assessment (Hyder *et al.* 2010). In biological surveys, the aims of such sampling are commonly to record the species present, to gain some measures of abundance and to examine assemblage structure, especially in determining the environmental sensitivity of an area that may be affected by a planned disturbance. Conservation studies may extend these aims by concentrating on the population dynamics of species, seeking to assess hypotheses related to decline or recovery. However, commonly used sampling techniques have biases, relative to other techniques, and a range of techniques should be employed in order to maximize the proportion of the reptile assemblage actually recorded (e.g., Friend *et al.* 1989; Morton *et al.* 1988; Enge 2001, Thompson and Thompson 2007, Sung *et al.* 2011). Estimates of absolute abundance can be obtained from mark-recapture studies that allow detection probabilities to be quantified, but these remain estimates with error variances (e.g., Meyler *et al.* 2012). Furthermore, some marking techniques may reduce survivorship (Ribeiro and Sousa 2006), and some small or juvenile lizards are notoriously hard to trap (Pike *et al.* 2008). Variation in trapping rates with changes in activity levels related to changes in structural complexity of the environment (Driscoll *et al.* 2012) add a further complication with trapping techniques that are dependent upon reptile activity for detection.

Even if biases relative to other capture techniques and habitat variables are understood, the relationship between the index of abundance obtained by any trapping procedure and the absolute abundance of the species is largely unknown. What is needed is an absolute measure of abundance that can provide a relationship with the index of abundance provided by trapping.

The determination of absolute abundance was investigated by Rodda *et al.* (2001), using a method referred to as a total removal plot, in tropical forest on the Pacific Ocean island of Guam, and by Craig *et al.* (2009), in eucalypt forest in the south-west of Western Australia. Rodda *et al.*

(2001) found unexpectedly high densities of lizards, that some species considered to be rare were actually locally common, and concluded that the technique provided a benchmark of absolute densities to which the results of other sampling techniques could be compared. Craig *et al.* (2009) compared results from total removal plots with results from pitfall trapping and similarly found large differences in the proportional representation of species between the two techniques.

Independently of the work by Rodda *et al.* (2001) and prior to that carried out by Craig *et al.* (2009), the opportunity arose during a field course for undergraduate students from Murdoch University, Western Australia, to carry out the total removal plot approach to produce absolute measures of abundance. This took place at two sites, with data from pitfall sampling available from one of the sites. These two sites, Cooljarloo and Jurien, lie within a region that has been recognised as being particularly rich in reptile species (Maryan 2006), and are therefore ideal for investigations into the composition of reptile assemblages. This paper presents measures of absolute abundance of reptiles, compares them with abundance indices obtained with pitfalls, and outlines the significance of the results for reptile conservation.

Methods

Study Area

The two study sites were located *ca.* 150 km north of Perth, Western Australia, and were *ca.* 50 km apart. Both pitfall trapping and systematic searching of total removal plots for reptiles were carried out at Cooljarloo, within the mining lease of Tronox (30° 40'S, 115° 25'E). Part of the mining lease was within unallocated crown land that supported *Banksia* low woodland and kwongan heath growing in sand underlain with clay and lateritic gravel (Delfs *et al.* 1987). The landscape was slightly undulating and the vegetation was floristically rich with subtle variations in floristic composition associated with topographical differences. It was dominated by members of the Myrtaceae and Proteaceae families, with *Banksia attenuata, Banksia menziesii* (Proteaceae) and scattered *Eucalyptus todtiana* (Myrtaceae) forming the overstorey in woodland areas. The second site, where only systematic searching was carried out, was located near the town of Jurien (30° 15'S, 115° 05'E). This was on private property supporting kwongan heath growing in shallow sand overlying limestone. The kwongan at this location consisted of a very floristically rich heathland with many of the same genera of Myrtaceae and Proteaceae present as at Cooljarloo. The vegetation at Jurien was generally denser than at Cooljarloo.

The climate in the region is Mediterranean with cool, wet winters and hot, dry summers. The town of Badgingarra, 30 km north of Cooljarloo, experiences a mean (1962-2004) maximum temperature in the hottest month (February) of 34.8°C, and a mean minimum in the coldest month (August) of 6.9° C. Average annual rainfall is 587.4 mm, with about 80% of this rain falling from May to September inclusive. Jurien experiences a slightly milder climate with a mean (1968-2005) maximum temperature in February of 30.7 °C and a mean minimum in August of 9.4 °C. Average annual rainfall is 559 mm (Bureau of Meteorology http://www.bom.gov.au/climate/).

Pitfall Sampling

Pitfall sampling at Cooljarloo was based on two transects of 20 L plastic buckets, each 28 cm in diameter and 40 cm deep, with the pitfalls 22.5 m apart. These transects were aligned east-west and were 400 m apart, with the northern transect (North Transect) consisting of 70 pitfalls, and the southern transect (South Transect) containing 68 pitfalls. They were, therefore, *ca.* 1.55 km and 1.51 km long, respectively. This layout was designed to sample reptiles and small mammals across slight variations in the landscape and vegetation associated with the swell and swale topography.

The pitfalls were used without drift-fences because the intention was to sample as large an area as possible with dispersed traps, not to maximise captures per pitfall. Pitfalls without drift-fences (unassisted pitfalls) are about half as effective as pitfalls with fences and capture the same suite of species, but with a lower representation of pygopodids and small snakes (Friend *et al.* 1989; Bamford and Bancroft unpublished), although the relationship between pitfall and fence layout is complex (Ellis 2013). Unassisted pitfalls were used by Davidge (1980) and Bamford (1995a) in long-term studies where large numbers of traps were deployed. This avoided the high maintenance involved with drift-fences that get damaged by wildlife and destroyed in fires. There were also concerns with introducing biases between pitfalls by using drift-fences, due to differences in vegetation along the transects and to fires that burnt through part of both transects and, therefore, altered vegetation density. In addition, the abundance of reptiles and small mammals at Cooljarloo meant that multiple captures occurred regularly, occasionally leading to specimens killing each other before traps could be cleared. Pitfalls were also, therefore, used without drift-fences to reduce mortality. Sung *et al.* (2011) report on the use of 'escape strings' to allow small mammals to exit pitfalls and thus reduce reptile mortality, but mammals were also of interest at Cooljarloo.

Sampling took place in late spring from 1990 to 2004 (except 1995 and 1996), with each sampling period lasting five nights. The total sampling effort in spring was 3,782 and 3,112 trap-nights in the North and South Transects respectively. Traps were checked once daily and were capped when not in use. Sampling also took place in winter but numbers of reptile captures were negligible in that season.

Capture data were pooled within each transect for the period 1990 to 2004 to produce total numbers of captures of each species, which were then expressed as proportions of total captures. Numbers of captures excluded specimens recaptured within a five day sampling period.

Total Removal Plots

Systematic searching of total removal plots was carried out at Cooljarloo in August 1993, 1994 and 1995, and at Jurien in August 1998 and 2001. Searching was carried out in winter because reptiles were expected to be inactive and, therefore, unlikely to escape. Searching was based on 5 m by 5 m (occasionally 4 m by 4 m or 6 m by 6 m) quadrats. Initially these were fenced with 0.5 m high plastic sheeting, although this was found to be unnecessary (because reptiles were inactive) and was discontinued. This approach was similar to that of Rodda *et al.* (2001), except that fencing of their quadrats was essential because of high levels of activity among the reptiles in the tropical climate of Guam, and because the rainforest provided a three dimensional environment in which reptiles moved. In contrast, at Cooljarloo and Jurien the environment was effectively two dimensional with all reptiles at or around ground level. Craig *et al.* (2009), also working in the south-west of Western Australia, also found fencing unnecessary to prevent the escape of reptiles during the cool winter months.

All searching at Cooljarloo was carried out in areas that were within the mine-path, so they were in areas that were to be cleared, and all plots were within 100 m of the pitfall transects. The searching at Jurien took place on private property. Total removal plots at Cooljarloo that were revisited after five years (where mining was delayed) were indistinguishable from surrounding vegetation due to regeneration from root-stock and seedling growth in the disturbed soil.

The total removal approach is illustrated in Plates 1 to 4 and had the following steps:

- Locations for plots were selected so that they included vegetation like that sampled by nearby pitfall traps. Plots were placed at least 25 m apart.
- The vegetation was described in terms of structure and general floristic composition, noting the dominant plant species present and the estimated percentage cover of the overstorey and understorey (<1 m).
- A team of at least five people surrounded the plot, corners were pegged and boundaries marked with coloured survey tape.
- A trench was quickly dug around the boundary of the plot to a depth of *ca.* 10 cm and a width of *ca.* 20 cm. Team-members not digging were responsible for watching for reptiles within the plot.
- Once the trench was dug, the team began working from the edges of the trench into the plot. This was done systematically, pruning bushes off at ground level with secateurs, raking leaf-litter out of the way and then digging through the soil to a depth of 10-15 cm with a three-pronged cultivator. Cultivators were usually used without a handle, so that the operator was kneeling and therefore very close to the soil being turned over. Team-members not engaged in pruning or digging kept watch around the plot.
- The systematic approach to searching was maintained until the entire plot had been searched. The aim was to work from the edges towards the centre of the plot so that the remaining unsearched area was roughly circular and a continuous, even searching front was achieved. Searching teams consisted of students who were closely supervised in order to maintain the standard of searching. The searching of each plot took 2-3 hours (10-15 person-hours).
- Reptiles found were captured and notes made of their location in the plot, depth in the soil and position relative to vegetation and leaf-litter. Specimens were identified and measured (snout to vent and total length) before being released.
- Although mining in the Cooljarloo area was imminent, leaf-litter and branches were placed back onto the plot at both Cooljarloo and Jurien to facilitate regeneration.

At Cooljarloo, 95 plots were searched over 3 years, giving a total searched area of 2,338 m^2. The majority of plots were in banksia low woodland typical of the area in general, but in 1995, 18 of the plots (430 m^2) were in an area that had been burnt 14 months previously, in autumn 1994. These 18 were excluded from further analysis as arboreal and semi-arboreal reptile species were almost absent, although terrestrial and fossorial species were present. Therefore, Cooljarloo data for only 77 plots with a total area of 1,908 m^2 were used.

At Jurien, 49 plots were searched in two years, giving a total searched area of 1,225 m^2. All were in heathland but, in 1998, one of the plots (25 m^2) was in a degraded area of vegetation close to cleared land. One reptile species, the small skink *Menetia greyii*, was extremely abundant in this plot. It was excluded and only data from the remaining 48 quadrats (1,200 m^2) were used in analyses.

Statistical Analysis

Differences in the reptile assemblages caught by pitfall trapping at the North and South Transects at Cooljarloo, and by systematic searching at Cooljarloo and Jurien, were explored using non-metric multidimensional scaling (nMDS), using the Bray-Curtis measure, to visualise differences (Clarke and Warwick 2001). This was followed with analysis of similarity (ANOSIM) (Clarke and Warwick 2001) to test for statistical differences between samples. Where ANOSIM was significant, we used similarity percentage (SIMPER) (Clarke 1993) to determine which reptile taxa were largely responsible for any differences observed. Drumm *et al.* (2011) give a recent example of the successive use of nMDS, ANOSIM and SIMPER. All analyses were performed using the PAST software package (Hammer 2001).

We treated successive years of sampling as replicates. Although sampling intensity varied from year to year and the reptile communities might also have varied annually, we reasoned that if hand capture was returning markedly different species to pitfall trapping then those differences should outweigh variation between annual samples using a particular method. As a further precaution, we compared the successive years of sampling at Cooljarloo by ANOSIM, treating the north and south transects as replicates in each year to test if successive years gave similar results. No pairwise comparison of years was statistically significant ($p > 0.32$ in all cases), so we concluded that our decision to treat successive years as replicates was justified.

Results

Numbers of captures in pitfalls and search areas

North and South Transects at Cooljarloo recorded similar numbers of species, 22 and 18 respectively, giving a total of 27 species caught in pitfalls (Table 1). A further 12 species were observed but not trapped. These were mostly species that are too large or slow-moving to become caught in pitfalls, such as large snakes and lizards, but included the small, fossorial pygopodid *Aprasia repens*.

The representation of each species was similar on the two transects, with the most abundant species being the agamids *Pogona minor* and *Ctenophorus adelaidensis*, and the skinks *Ctenotus fallens, Ctenotus impar* and *Morethia obscura*. These are all diurnal, fast-moving and surface-active species, and on North and South Transects pooled made up 88.8 % of all captures (Table 1). Pygopodids, geckoes, small skinks and

Table 1. Results of pitfall sampling and systematic searching at Cooljarloo and Jurien; numbers of captures and percentage of each species in total captures for each technique. NA indicates species recorded at Jurien but not at Cooljarloo, where intensive sampling indicates these species are not present. An asterisk indicates species not recorded at a site by pitfall trapping or searching, but which have been observed.

	Cooljarloo Pitfall Transects			Searching		Jurien Searching	
Species	North	South	%	N	%	N	%
Pygopodidae (legless lizards)							
Aclys concinna	**2**	**0**	**0.1**	**7**	**8.4**	**0**	**0**
Aprasia repens	0	0	**0**	1	**1.2**	0	**0**
Delma fraseri	3	0	**0.2**	0	**0**	0	**0**
Delma grayii	0	0	*	0	**0**	0	**0**
Lialis burtonis	0	0	**0**	3	**3.6**	2	**1.7**
Pletholax gracilis	0	3	**0.2**	2	**2.4**	2	**1.7**
Pygopus lepidopodus	0	0	*	0	**0**	1	**0.9**
Gekkonidae (geckoes)							
Crenadactylus ocellatus	0	0	*	0	**0**	0	**0**
Diplodactylus polyophthalmus	0	0	*	0	**0**	0	**0**
Lucasium alboguttatum	3	3	**0.4**	1	**1.2**	0	**0**
Strophurus spinigerus	25	14	**2.6**	10	**12.0**	9	**7.8**
Christinus marmoratus	0	1	**0.5**	0	**0**	0	**0**
Agamidae (dragon lizards)							
Pogona minor	100	93	**12.9**	1	**1.2**	0	*
Ctenophorus adelaidensis	283	287	**38.2**	7	**8.4**	0	**0**
Varanidae (monitor lizards)							
Varanus gouldii	0	0	*	0	**0**	0	**0**
Scincidae (skink lizards)							
Ctenotus gemmula	11	8	**1.3**	1	**1.2**	0	**0**
Ctenotus fallens	155	195	**23.4**	4	**4.8**	5	**4.3**
Ctenotus impar	63	25	**5.9**	0	**0**	0	**0**
Ctenotus australis	5	3	**0.5**	0	**0**	0	**0**
Ctenotus pantherinus	5	0	**0.3**	0	**0**	0	**0**
Cryptoblepharus buchanani	10	5	**1.0**	0	**0**	0	**0**
Cyclodomorphus celatus	0	0	*	0	**0**	2	**1.7**
Egernia multiscutata	0	0	*	0	**0**	0	**0**
Egernia napoleonis	2	0	**0.1**	0	**0**	0	**0**
Lerista christinae	0	0	*	0	**0**	0	**0**
Lerista elegans	1	0	**0.1**	1	**1.2**	7	**6.1**
Lerista lineopunctulata	-	-	NA			1	**0.9**
Lerista praepedita	33	10	**2.9**	20	**24.1**	62	**53.9**
Menetia greyii	0	0	**0**	0	**0**	12	**10.4**
Morethia lineoocellata	2	3	**0.3**	0	**0**	0	**0**
Morethia obscura	68	57	**8.4**	18	**21.7**	0	**0**
Tiliqua occipitalis	0	0	*	0	**0**	0	**0**
Tiliqua rugosa	0	1	**0.1**	2	**2.4**	4	**3.5**
Typhlopidae (blind snakes)							
Ramphotyphlops australis	3	4	**0.5**	2	**2.4**	0	**0**
Boidae (pythons)							
Morelia spilota	0	0	*	0	**0**	0	**0**
Elapidae (front-fanged snakes)							
Brachyurophis fasciolata	0	1	**0.1**	0	**0**	0	**0**
Echiopsis curta	0	2	**0.1**	1	**1.2**	2	**1.7**
Pseudechis australis	0	0	*	0	**0**	0	**0**
Pseudonaja mengdeni	1	0	**0.1**	0	**0**	0	**0**
Parasuta gouldii	1	0	**0.1**	0	**0**	0	**0**
Neelaps bimaculata	1	0	**0.1**	0	**0**	0	**0**
Neelaps calonotos	2	0	**0.1**	0	**0**	0	**0**
Simoselaps littoralis	-	-	NA			6	**5.2**
TOTALS (number of captures):	749	715					
	1464			83		115	

Table 2. Estimated densities per ha of reptiles at Cooljarloo and Jurien, based on the numbers of each species caught in 1 908m^2 at Cooljarloo and 1 200m^2 at Jurien. Question marks indicate species known or suspected to occur in an area but for which no density estimate is available. Weights are maxima and are taken from unpublished records (M. Bamford) from a variety of sites within 100km of Cooljarloo. The snout-vent length or average total length are taken from unpublished records (M. Bamford) and Cogger (1996).

Species	Weight (g)	Snout-vent length *Average total length (mm)	Cooljarloo N/ha	Jurien N/ha
Lucasium alboguttatum	4	55	5.2	?
Strophurus spinigerus	5	60	52.4	75.0
Aclys concinna	2	75	36.7	?
Aprasia repens	1	110	5.2	?
Lialis burtonis	10	250	15.7	16.7
Pygopus lepidopodus	20	230	?	8.3
Pletholax gracilis	3	75	10.5	16.7
Pogona minor	40	110	5.2	?
Ctenophorus adelaidensis	5	45	36.7	?
Cryptoblepharus buchanani	2	45	10.5	?
Ctenotus fallens	15	90	21.0	41.7
Ctenotus gemmula	10	50	5.2	?
Cyclodomorphus celatus	10	75	0	16.3
Lerista elegans	<1.0	40	5.2	58.3
Lerista lineopunctulata	<1.0	100	0	8.3
Lerista praepedita	<1.0	60	104.8	516.7
Menetia greyii	<1.0	30	?	100.0
Morethia obscura	2.5	50	94.3	?
Tiliqua rugosa	500	320	10.5	33.3
Ramphotyphlops australis	15	250*	10.5	?
Echiopsis curta	20	400*	5.2	16.3
Simoselaps littoralis	10	300*	0	50.0
TOTAL			429.8	958.3

small snakes were caught infrequently, with 16 species each representing <1% of all captures.

Searching recorded 17 species at Cooljarloo and 13 at Jurien where a smaller area was searched (Table 1). Many species were present at both sites, but the skink *Lerista lineopunctulata*, and the elapid snake *Simoselaps littoralis* were recorded only at Jurien. Given the intensity of survey work at Cooljarloo, it is considered that these two species are absent from that site.

nMDS indicated substantial overlap between the reptile assemblages caught by pitfall trapping at Cooljarloo North and South Transects, but marked differences between these and the assemblages caught by systematic searching at either Cooljarloo or Jurien (Fig. 1). This interpretation was supported by ANOSIM, which found statistically significant differences between transect and systematic searching results at Cooljarloo and Jurien, but not between the North and South Transects and not between the systematic searching results at Cooljarloo and Jurien. The R values for the significant results all exceeded 0.78, indicating strong dissimilarity (Table 3). SIMPER revealed that *Lerista praepedita*, *C. adelaidensis* and *C. fallens* accounted for 57.4% of the differences between the North pitfall transect and the Jurien systematic searching captures, and 62.6% of the differences between the South pitfall transect and the Jurien systematic searching captures. At Cooljarloo, *C. adelaidensis, C. fallens* and *P. minor* were responsible for 52.8% of the differences between the North pitfall transect and the systematic searching captures, while *C. adelaidensis,*

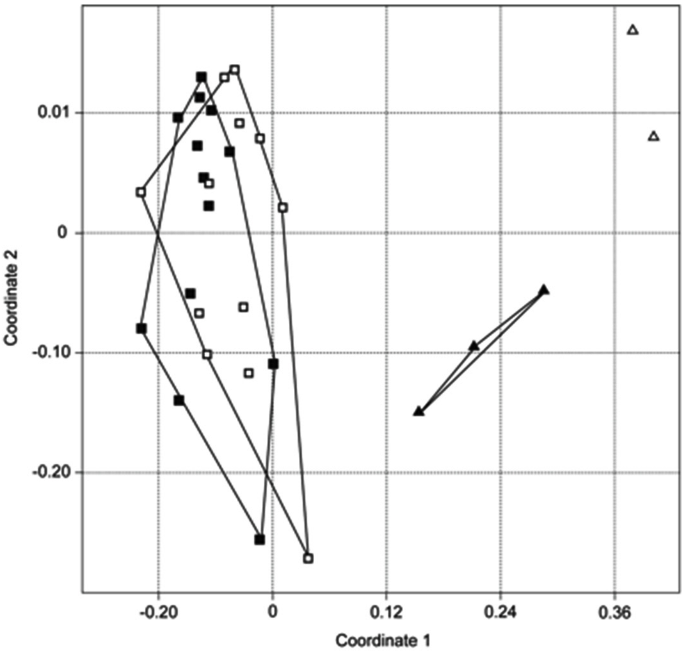

Figure 1. nMDS of the similarity of reptile assemblages obtained by pitfall trapping at Cooljarloo north transect, Cooljarloo south transect, systematic searching at Cooljarloo and systematic searching at Jurien. Minimum convex hulls (the smallest polygon that embraces all points) are shown for each group. The stress value was 0.1124. Open squares: Cooljarloo North Transect. Closed squares: Cooljarloo South Transect. Closed diamonds: Cooljarloo systematic searching. Open diamonds: Jurien systematic searching.

Table 3. ANOSIM results for comparisons between the reptile assemblages caught using pitfall trapping or systematic searching at Cooljarloo and systematic searching at Jurien. P-values are in plain text and R values in italics.

	North	South	Search	Jurien
North	0	0.87	<0.01	0.01
South	*-0.05*	0	<0.01	0.01
Search	*0.78*	*0.83*	0	0.1
Jurien	*0.97*	*1.00*	*0.83*	0

C. fallens and *L. praepedita* were responsible for 58.4% of the differences between the South pitfall transect and the systematic searching captures (Tables 4 and 5).

In summary, the most notable differences and similarities between the two sampling techniques were:

- The large skink *C. fallens* represented 4.8 % and 4.3 % in plot samples at Cooljarloo and Jurien respectively, but 23.4 % of the pitfall sample at Cooljarloo;
- the fossorial skink *Lerista praepedita* represented 24.1 % and 53.9 % in plot samples at Cooljarloo and Jurien respectively, but only 2.9 % of the pitfall sample at Cooljarloo;
- Pygopodids were consistently better represented in plot samples than in pitfall samples;
- Both agamids were better represented in pitfall than in plot samples (for *P. minor* 12.9 % compared with 1.2 %, and for *C. adelaidensis* 38.2 % compared with 8.4 %);
- The arboreal gecko *S. spinigerus* was less well-represented in pitfall (2.6 %) than in plot samples (12.0 %);
- The small, surface-active skink *M. obscura* was the fourth most abundant species in the pitfall sample (8.4 %) and was the second most abundant species in plot samples at Cooljarloo (21.7 %). It was absent from Jurien. This was the only species well-represented with both sampling techniques;
- The very large, slow-moving skink *Tiliqua rugosa* was poorly represented in pitfall samples;
- Snakes in general were poorly-represented with both sampling techniques, although one species, *Echiopsis curta*, was better-represented in plot samples (1.2 % and 1.7 % at Cooljarloo and Jurien respectively) than in pitfall samples (0.1 %).

Table 4. SIMPER results indicating the percentage of the differences between reptile assemblages found significant by ANOSIM that were attributable to particular species in comparisons involving the Cooljarloo North Transect.

Cooljarloo North Transect vs Cooljarloo systematic searching			Cooljarloo North Transect vs Jurien systematic searching		
Species	%	Cumulative %	Species	%	Cumulative %
Ctenophorus adelaidensis	28.0	28.0	*Lerista praepedita*	28.9	28.9
Ctenotus fallens	14.7	42.6	*Ctenophorus adelaidensis*	19.7	48.6
Pogona minor	10.1	52.8	*Ctenotus fallens*	8.8	57.4
Morethia obscura	9.7	62.4	*Pogona minor*	6.8	64.2
Lerista praepedita	8.8	71.2	*Menetia greyii*	5.9	70.1
Ctenotus impar	7.9	79.2	*Morethia obscura*	5.9	75.9
Strophurus spinigerus	5.3	84.4	*Ctenotus impar*	4.9	80.8
Delma grayii	3.9	88.3	*Lerista elegans*	4.1	84.9
Lialis burtonis	1.8	90.1	*Strophurus spinigerus*	3.6	88.4
Cryptoblepharus buchanani	1.7	91.8	*Simoselaps littoralis*	3.3	91.7
Ctenotus gemmula	1.3	93.1	*Cyclodomorphus celatus*	1.1	92.8
Pletholax gracilis	1.3	94.4	*Lialis burtonis*	0.9	93.7
Ramphotyphlops australis	1.3	95.7	*Pletholax gracilis*	0.9	94.5
Lucasium alboguttatum	0.8	96.5	*Echiopsis curta*	0.9	95.4
Echiopsis curta	0.7	97.2	*Ctenotus gemmula*	0.8	96.2
Lerista elegans	0.7	97.8	*Cryptoblepharus buchanani*	0.7	96.9
Ctenotus australis	0.4	98.2	*Lerista lineopunctulata*	0.7	97.6
Ctenotus pantherinus	0.4	98.6	*Pygopus lepidopodus*	0.4	98.0
Morethia lineoocellata	0.3	99.0	*Ctenotus australis*	0.3	98.3
Delma fraseri	0.3	99.3	*Ctenotus pantherinus*	0.3	98.6
Egernia napoleonis	0.3	99.5	*Ramphotyphlops australis*	0.2	98.8
Neelaps calonotus	0.2	99.7	*Lucasium alboguttatum*	0.2	99.0
Parasuta gouldii	0.2	99.9	*Delma fraseri*	0.2	99.2
Neelaps bimaculata	0.1	99.9	*Morethia lineoocellata*	0.2	99.4
Pseudonaja mengdeni	0.1	100.0	*Egernia napoleonis*	0.2	99.6
Pygopus lepidopodus	0.0	100.0	*Delma grayii*	0.1	99.7
Brachyurophis fasciolata	0.0	100.0	*Neelaps calonotus*	0.1	99.8
Christinus marmoratus	0.0	100.0	*Parasuta gouldii*	0.1	99.9
Menetia greyii	0.0	100.0	*Pseudonaja mengdeni*	0.0	100.0
Lerista lineopunctulata	0.0	100.0	*Neelaps bimaculata*	0.0	100.0
Cyclodomorphus celatus	0.0	100.0	*Brachyurophis fasciolata*	0.0	100.0
Simoselaps littoralis	0.0	100.0	*Christinus marmoratus*	0.0	100.0

Species that were well-represented in pitfalls were quadruped, pentadactyl, surface active and fast-moving. Most were also moderately large (Table 2). In contrast, species well-represented in searching were more variable, with many being limbless or short-limbed (*A. concinna, A. repens, L. burtonis, L. elegans, L. praepedita, S. littoralis*), and most being either fossorial (*A. repens, L. elegans, L. praepedita, S. littoralis*) or arboreal (*A. concinna, S. spinigerus*). The most abundant species in searching, the skink *L. praepedita*, is extremely small (<1 g). Only *M. obscura*, a small but surface-active skink with well-developed limbs, was well-represented with both sampling techniques. *M. greyii*, a small (<1 g), surface-active skink, was well-represented in the searching data at Jurien but was not present in the sampling area at Cooljarloo. Some species are illustrated in Plates 5 to 9.

Density estimates from systematic searching

At Cooljarloo, 83 specimens of 17 reptile species were caught, with an overall density of 429.8 reptiles/ha (Table 2). Fewer species (13) but more individuals (115) were recorded at Jurien, with an overall density of 958.3/ha (Table 2); twice that found at Cooljarloo. The much greater density at Jurien was due to two very abundant skinks: *L. praepedita* (516.7/ha at Jurien compared with 104.8/ha at Cooljarloo) and *M. greyii* (100.0/ha at Jurien and not found in search areas at Cooljarloo, although present in the area). *L. praepedita* was the most abundant species at both sites. The lower number of species at Jurien is probably due to the smaller area searched (1,200 m^2 compared with 1,908 m^2). For a few species, such as the gecko *S. spinigerus* and the pygopodid *L. burtonis*, estimated densities at the two sites are similar. For most species, however, estimated densities differ greatly.

Results from systematic searching represent only a small proportion of the reptile assemblage of each site. At Cooljarloo, the 17 species recorded by systematic searching represent 44% of the known reptile assemblage (Bamford 1995b). These are presumably the most abundant or widespread species. At Cooljarloo, the 22 species that were not found during searching were either absent from the region where searching was carried out or occur at very low densities. Since these species were not found in the 1,908 m^2 searched, they must collectively occur at a density of <5.2/ha (the density of 1 specimen found in 1,908 m^2). These unrecorded species therefore have little effect on the total density, but not all may be present in any one area and those that are present cannot be assumed to occur at the same density, so the estimated density for each unrecorded species has to be <5.2/ha.

Table 5. SIMPER results indicating the percentage of the differences between reptile assemblages found significant by ANOSIM that were attributable to particular species in comparisons involving the Cooljarloo South Transect.

Cooljarloo South Transect vs Cooljarloo systematic searching			Cooljarloo South Transect vs Jurien systematic searching		
Species	%	Cumulative %	Species	%	Cumulative %
Ctenophorus adelaidensis	28.9	28.9	*Lerista praepedita*	30.7	30.7
Ctenotus fallens	18.6	47.6	*Ctenophorus adelaidensis*	20.7	51.4
Lerista praepedita	10.9	58.4	*Ctenotus fallens*	11.2	62.6
Pogona minor	9.7	68.1	*Pogona minor*	6.6	69.2
Morethia obscura	9.2	77.4	*Menetia greyii*	5.9	75.1
Strophurus spinigerus	5.4	82.8	*Morethia obscura*	4.9	80.0
Delma greyii	4.1	86.8	*Lerista elegans*	4.2	84.2
Ctenotus impar	3.2	90.0	*Strophurus spinigerus*	3.5	87.8
Lialis burtonis	1.8	91.8	*Simoselaps littoralis*	3.3	91.1
Cryptoblepharus buchanani	1.5	93.3	*Ctenotus impar*	2.0	93.0
Ramphotyphlops australis	1.3	94.6	*Cyclodomorphus celatus*	1.1	94.1
Pletholax gracilis	1.3	95.9	*Pletholax gracilis*	0.9	95.0
Ctenotus gemmula	1.0	96.9	*Echiopsis curta*	0.9	95.9
Lucasium alboguttatum	0.8	97.7	*Lialis burtonis*	0.9	96.8
Echiopsis curta	0.8	98.5	*Lerista lineopunctulata*	0.7	97.5
Lerista elegans	0.6	99.1	*Ctenotus gemmula*	0.6	98.0
Morethia lineoocellata	0.4	99.5	*Pygopus lepidopodus*	0.4	98.5
Ctenotus australis	0.3	99.8	*Ramphotyphlops australis*	0.4	98.9
Brachyurophis fasciolata	0.1	99.9	*Cryptoblepharus buchanani*	0.4	99.3
Christinus marmoratus	0.1	100.0	*Morethia lineoocellata*	0.2	99.5
Neelaps bimaculata	0.0	100.0	*Ctenotus australis*	0.2	99.7
Neelaps calonotus	0.0	100.0	*Lucasium alboguttatum*	0.2	99.9
Parasuta gouldii	0.0	100.0	*Brachyurophis fasciolata*	0.1	99.9
Pygopus lepidopodus	0.0	100.0	*Christinus marmoratus*	0.1	100.0
Menetia greyii	0.0	100.0	*Neelaps bimaculata*	0.0	100.0
Lerista lineopunctulata	0.0	100.0	*Neelaps calonotus*	0.0	100.0
Delma fraseri	0.0	100.0	*Parasuta gouldii*	0.0	100.0
Egernia napoleonis	0.0	100.0	*Delma fraseri*	0.0	100.0
Cyclodomorphus celatus	0.0	100.0	*Egernia napoleonis*	0.0	100.0
Pseudonaja mengdeni	0.0	100.0	*Pseudonaja mengdeni*	0.0	100.0
Simoselaps littoralis	0.0	100.0	*Ctenotus pantherinus*	0.0	100.0
Ctenotus pantherinus	0.0	100.0	*Delma greyii*	0.0	100.0

Table 6. Relationship of each species with environmental parameters, indicating the number of specimens of each species for which location was recorded with respect to position either in a shrub, on the soil surface or depth in the soil. The presence of vegetation cover for specimens found on or in the soil is also indicated, but was only recorded for some specimens. Cooljarloo and Jurien data pooled.

Species	In shrub	Surface	Depth (cm)			Cover	
			1-3	4-6	>6	+	-
Lucasium alboguttatum		1				1	
Strophurus spinigerus	8	7				5	
Aclys concinna		6				6	
Aprasia repens			1				
Lialis burtonis		4				3	
Pygopus lepidopodus		1				1	
Pletholax gracilis		1	1	1		2	1
Pogona minor		2				2	
Ctenophorus adelaidensis		2	2	1		2	1
Cryptoblepharus buchanani	1						
Ctenotus fallens		3	4	1		9	
Ctenotus gemmula		1				1	
Cyclodomorphus celatus			1	1		1	1
Lerista elegans		1	6	2		5	4
Lerista lineopunctulata			1				1
Lerista praepedita		1	38	34	7	34	42
Menetia greyii		6	3	1	3	7	4
Morethia obscura		11	2	2	2	12	2
Tiliqua rugosa		5				6	
Ramphotyphlops australis			1				
Echiopsis curta		2	1			3	
Vermicella littoralis			1	4		3	3

Micro-habitat locations recorded during systematic searching

Over 90% of reptiles found were noted as being torpid. The remaining specimens were active but lethargic, as expected for cool winter days. Two arboreal species were found in shrubs, with specimens of the gecko *S. spinigerus* also found on the surface, believed to be specimens that had dropped from bushes during clearing. All other specimens were found either on or beneath the soil surface (Table 6). Specimens found in the soil were at depths of up to 10 cm, which was the effective searching depth, but 90.1% of specimens found buried were at depths of <6 cm. This suggests that few specimens were to be found at depths >10 cm. Over half (63.6 %) the specimens on or in the soil were under cover of vegetation (including leaf-litter), with the remaining specimens in the soil with no such cover. In the case of the most abundant reptile species, *L. praepedita*, under half (44.7 %) of specimens were found under cover of vegetation. Specimens that were not found under cover of vegetation were under bare sand between bushes (Table 6).

Discussion

Reliability of data from systematic searching

Systematic searching is a novel sampling technique that has been used in few studies (Rodda *et al.* 2001, Heatwole and Butler 1981, Craig *et al.* 2009), and is only briefly mentioned in a major review of reptile sampling techniques (McDiarmid *et al.* 2012). It resembles the searching of litter plots, but these are generally small (e.g. 1 m^2), do not usually employ search area barriers and do not remove vegetation or excavate through the topsoil. Rodda *et al.* (2001) suggest that litter plots may under-sample terrestrial lizard species. Sung *et al.* (2011) conducted intensive searching along 100 m by 2 m transects but this did not provide absolute density data.

The novelty of the systematic searching approach means the assumption that results provide absolute measures of population density has to be questioned. The technique does involve an element of skill but results were similar across years at Cooljarloo and Jurien, and while different groups of students worked in different years, the same staff supervised them closely. There is nothing from observations to suggest that reptiles were escaping from the quadrats because reptiles were generally inactive. This was also found by Craig *et al.* (2009). The technique would be much less reliable at a warm time of the year. The depths at which specimens were found suggest that few were at depths greater than those to which searching was carried out. The most likely source of error was that some small, fossorial skinks may have been missed because they often did not move and therefore may have been overlooked. Rodda *et al.* (2001) were confident of the validity of their total removal plot approach, but concluded that individuals of the small, arboreal species that dominated their samples may have been missed if they fell to the ground and concealed themselves in leaf-litter. They also suggested that results would be biased by site selection in an environment dominated by large trees that could not be included in removal plots, but at both Cooljarloo and Jurien the largest plants were large bushes to 2 m (Jurien) and small trees to 5 m (Cooljarloo), with stem diameters rarely up to 30cm. Differences in densities between Cooljarloo and Jurien are believed to be real.

Comparison of pitfall and systematic searching data

If the results of systematic searching closely reflect absolute levels of abundance, then the results from pitfall trapping are highly biased. Pitfall traps under-sample the most abundant reptiles in the assemblage at Cooljarloo, particularly pygopodids and small, fossorial skinks, and greatly over-estimate the abundance of moderate-sized, surface active reptiles such as *C. adelaidensis*. Arboreal and large, slow moving species, such as *T. rugosa*, also appear to be under-sampled with pitfalls.

The skink *M. obscura* was the only species that was well-represented with both sampling techniques (8.4% in pitfalls and 21.7% in searching at Cooljarloo; not caught at Jurien). It is the smallest of the species well-represented in pitfalls but is larger and more surface-active than the other skink species well-represented in searching. The searching results suggest that it does occur at a high density, unlike other species well-represented in pitfalls. Moreover, its behaviour and morphology make it more liable to fall into pitfalls than other species well-represented in searching. It is the only species in the reptile assemblage at Cooljarloo that is both abundant and has features that make it liable to fall into pitfalls. The same may be true of the smaller but morphologically similar *M. greyii*, caught only at Jurien.

This result has implications for any attempt to characterise a reptile assemblage on the basis of pitfall data alone. Furthermore, it is likely that any trapping technique that relies on reptile behaviour to effect capture will be strongly biased in favour of medium-sized, surface-active species, which will therefore be over-represented in samples. For example, Enge (2001) and Thompson and Thompson (2007) have found funnel traps, which rely on reptiles entering a funnel level with the surface of the ground, to represent snakes, pygopodids and some terrestrial lizards more strongly than pitfalls, but to under-represent fossorial and semi-fossorial species to an even greater extent than pitfalls.

At least at the two study sites examined, the most abundant components of the reptile assemblage, small, fossorial skinks, are grossly under-represented by pitfall sampling and this may be a common pattern. The Jurien and Cooljarloo sites, however, may be unusual in supporting reptile assemblages with such a dominance of small, fossorial skinks. Despite this, the results indicate how pitfall data may be interpreted in relation to absolute density of a species through reference to a species' morphology and lifestyle. The results also reinforce the conclusions of other authors that multiple procedures should be used when sampling for reptiles, and further suggest that some form of intensive if not systematic searching should be included.

Micro-habitat

The recording of micro-habitat data provided information on the ecology of each species and on the robustness of the searching data, but also revealed that, when inactive, a large proportion of reptiles shelter in the soil where vegetation cover is absent. This has implications for programs of habitat restoration and minesite rehabilitation and suggests an important area of further research with respect to ecosystem restoration.

Comparison with other studies

Very few studies have attempted to determine absolute measures of abundance of reptiles against which we could benchmark the densities at Cooljarloo and Jurien and other sites. An exception is the study carried out by Rodda *et al.* (2001) on Guam, where intensive searching of fenced 100 m^2 quadrats recorded total lizard densities of 1,600 to 70,900/ha. The much higher density compared with Cooljarloo and Jurien may reflect the productivity and structural complexity of a tropical rainforest environment. No information on the number of plots searched or on the abundance of individual species was provided, except that the single most abundant species occurred at a density of 67,600/ha.

Craig *et al.* (2009), using the same approach as in the present study, found less difference between pitfall trapping and searching results, but were working in an environment with a rocky substrate and therefore fossorial reptile species were a minor component of the assemblage; captures were dominated by a suite of small, primarily litter-dwelling skinks. Despite this, only two of the five species recorded in both pitfalls and removal plots had a significant correlation in abundance between the two sampling techniques, with the remaining three species more abundant (and therefore apparently over-represented) in pitfall samples. These three species included two recorded in the present study: *M. greyii* and *M. obscura*. The overall reptile density was 522 individuals/ha, similar to that found at Cooljarloo.

In a somewhat similar study, Heatwole and Butler (1981) found a total lizard density of 324/ha on Barrow Island, a semi-arid environment (annual rainfall 320 mm, Bureau of Meteorology, http://bom.gov.au/climate/) of tussock grasslands off the north-west coast of Australia. This was based on searching a single quadrat of 1,175m^2. This study had no data collected with pitfalls or other trapping techniques for comparison, but pitfall trapping has subsequently taken place on Barrow Island (M. Bamford unpubl. data). Comparison of searching and pitfall data from Barrow Island reveals a similar bias in the pitfall data as observed at Cooljarloo. The three most abundant species in the searching data, each with 6 captures (15.8% of the 38 captures in total) were an arboreal gecko *Diplodactylus jeanae* (1% of 700 pitfall captures) and two short-limbed skinks that inhabit dense vegetation at ground level: *Cyclodomorphus melanops* (0.5% of pitfall captures) and *Proablepharus reginae* (0.3% of pitfall captures).

Implications for conservation

Systematic searching allows for the calculation of absolute densities of reptiles and can reveal a very different composition to reptile assemblages than that found with pitfall trapping, and probably other trapping techniques that rely on interception of moving animals. Importantly, it indicates that arboreal, semi-fossorial and fossorial reptile species, particularly those that are small, are likely to be under-represented in trapping data, while surface-active species may be over-represented. If this is generally applicable, then searching provides a guideline for the interpretation of capture results from other techniques, with this interpretation based on the morphology and life history features of each species. Where site-specific searching and pitfall data are available, it may be possible to adjust pitfall data to provide an estimate of absolute abundance. While it is recognised that plot searching is destructive of habitat, observations at Cooljarloo indicated that regeneration was rapid and, where land-clearing is going to occur as part of development, plot-searching is an effective use of habitat that will be destroyed anyway.

These conclusions have important implications for conservation. Firstly, presence/absence or relative abundance studies intended to assess reptile faunas before or after a planned disturbance will benefit from calibration by direct searching to locate and identify the small lizard community. Secondly, direct searching can provide vital demographic data for diagnosing declines and recoveries. Pike *et al.* (2008) concluded that the common assumption of high mortality rates in juvenile lizards is probably mistaken, based on calculations of the juvenile survivorships necessary to sustain observed adult populations. Sampling techniques designed to correct for the capture biases they acknowledge with small or juvenile lizards would greatly improve the development of life tables and similar demographic techniques for studying endangered lizard populations.

Acknowledgements

This work was carried out by undergraduate students as part of a unit at Murdoch University. Thanks go to university unit coordinator Dr P. Ladd and colleague Dr S. Davies for their support. Ms J. Wilcox assisted in student management at Jurien. While the students are too numerous to list individually, we would like to express our thanks for their enthusiasm at what may have seemed, at the time, an outrageous activity. Tronox supported the work and provided access to its lease area at Cooljarloo, while John and Noel Grigson of Cockleshell Gully Farm allowed us to work on their property. Unpublished data from Barrow Island are used with permission from the Gorgon Joint Venture partners. Drs Wes Bancroft and Mike Craig provided comments on a draft of this paper, as did an anonymous reviewer.

References

Bamford, M.J. 1995a. Responses of reptiles to fire and increasing time after fire in *Banksia* woodland. *CALMScience Supplement* **4:** 175-186.

Bamford, M.J. 1995b. Predation by feral cats upon lizards. *Western Australian Naturalist* **20:** 191-196.

Bamford, M., Dunlop, N., Gamblin, T. and Bamford, A. 2013. *Fauna Sampling Manual. Guide To Sampling Techniques For Wildlife Research In Western Australia.* Conservation Council of WA, Perth.

Clarke, K. R. 1993. Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology* 18: 117-143. http://dx.doi.org/10.1111/j.1442-9993.1993.tb00438.x

Clarke, K.R. and Warwick, R.M. 2001. *Change in Marine Communities: An Approach to Statistical Analysis and Interpretation.* PRIMER-E Ltd., Plymouth, UK.

Cogger, H.G. 1996. *Reptiles and Amphibians of Australia.* A.H. & A.W. Reed, Sydney.

Craig, M.D., Grigg, A.H., Garkaklis, M.J., Hobbs, R.J., Grant, C.D., Fleming, P.A. and Hardy, G.E. 2009. Does habitat structure influence capture probabilities? A study of reptiles in eucalypt forest. *Wildlife Research.* **36:** 509-515. http://dx.doi.org/10.1071/WR09014

Davidge, C. 1980. Reproduction in the herpetofaunal community of a banksia woodland near Perth, WA. *Australian Journal of Zoology* **28:** 435-443.

Delfs, J. C., Pate, J. S. and Bell, D. T. 1987. Northern Sandplain kwongan: community biomass and selected species response to fire. *Journal of the Royal Society of Western Australia* **69:** 133-138.

Driscoll, D. A., Smith, A.L., Blight, S. and Maindonald, J. 2012. Reptile responses to fire and the risk of post-fire disturbance sampling bias. *Biodiversity Conservation* **21:** 1607-1625. http://dx.doi.org/10.1007/s10531-012-0267-5

Drumm, D.J., Loneragan, N.R., Ellis, N. and Skilleter, G.A. 2011. The significance of habitat and exposure to the reef-flat macroinvertebrates of Rarotonga, Cook Islands, for conservation planning. *Pacific Conservation Biology* **17:** 320-337.

Ellis, M. 2013. Impacts of pit size, drift fence material and fence configuration on capture rate of small reptiles and mammals in New South Wales rangelands. *Australian Zoologist* **36:** 404-412. http://dx.doi.org/10.7882/AZ.2013.005

Enge, K.M. (2001). The pitfalls of pitfall traps. *Journal of Herpetology* 35: 467-478. http://dx.doi.org/10.2307/1565965

Friend, G.R., Smith, G.T., Mitchell, D.S. and Dickman, C.R. 1989. Influence of pitfall and drift fence design on capture rates of small vertebrates in semi-arid habitats of Western Australia. *Australian Wildlife Research.* **16:** 1-10. http://dx.doi.org/10.1071/WR9890001

Hammer, Ø., Harper, D.A.T., and Ryan, P. D. 2001. PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica* **4:** 9pp.

Heatwole, H. and Butler, H. 1981. Structure of an assemblage of lizards on Barrow Island, Western Australia. *Australian Journal of Herpetology* **1:** 37-44.

Hyder, B.M., Dell, J. and Cowan, M.A. 2010. *Technical Guide – Terrestrial Fauna Surveys for Environmental Impact Assessment.* Technical report of the Environmental Protection Authority and the Department of Environment and Conservation, Perth.

Maryan, B. 2006. A herpetofaunal hotspot, the central west coast of Western Australia. *The Western Australian Naturalist* **25:** 1-24.

McDiarmid, R.W., Foster, M.S., Guyer, C., Gibbons, J.W. and Chernoff, N. 2012. *Reptile Biodiversity. Standard Methods for Inventory and Monitoring.* University of California Press, Berkeley.

Meyler, S. V., Salmona, J., Ibouroi, M. T., Besolo, A., Rasolondraibe, E., Radespiel, U., Rabarivola, C. and Chikhi, L. 2012. Density estimates of two endangered nocturnal lemur species from northern Madagascar: new results and a comparison of commonly used methods. *American Journal of Primatology* **74:** 414-422. http://dx.doi.org/10.1002/ajp.21997

Morton, S.R., Gillam, M.W., Jones, K.R. and Fleming, M.R. 1988. Relative efficiency of different pit-trap systems for sampling reptiles in spinifex grasslands. *Australian Wildlife Research* **15:** 571-577. http://dx.doi.org/10.1071/WR9880571

Pike, D. A., Peterman, K. S. and Exum, J. H. 2008. Habitat structure influences the presence of sand skinks (*Plestiodon reynoldsi*) in altered habitats. *Wildlife Research* **35:** 120-127. http://dx.doi.org/10.1071/WR07119

Ribeiro, L. B. and Sousa, B. M. 2006. Elastic hair bands: An effective marking technique for lizards in mark-recapture studies. *Herpetological Review* **37:** 434-435.

Rodda, G., Campbell, E.W. and Fritts, T.H. 2001. A high validity census technique for herpetofaunal assemblages. *Herpetological Review* **32:** 24-30.

Sung, Y., Karraker, N.F. and Han, B.C. H. 2011. Evaluation of the effectiveness of three survey methods for sampling terrestrial herpetofauna in South China. *Herpetological Conservation and Biology* **6:** 479-489.

Thompson, G.G. and Thompson, S.A. 2007. Usefulness of funnel traps in catching small reptiles and mammals, with comments on the effectiveness of alternatives. *Wildlife Research* **34:** 491-497. http://dx.doi.org/10.1071/WR06081

APPENDIX I

Plate 1. Jurien; team has cleared the perimeter and is starting to work into the quadrat. The tape measure marking the quadrat boundary is just visible in the foreground (M. Bamford).

Plate 2. Jurien; team surrounding last patch of uncleared, undug soil in the quadrat (M. Bamford).

Plate 3. Jurien; team in completed quadrat (M. Bamford).

Plate 4. Jurien; team rehabilitating completed quadrat (M. Bamford).

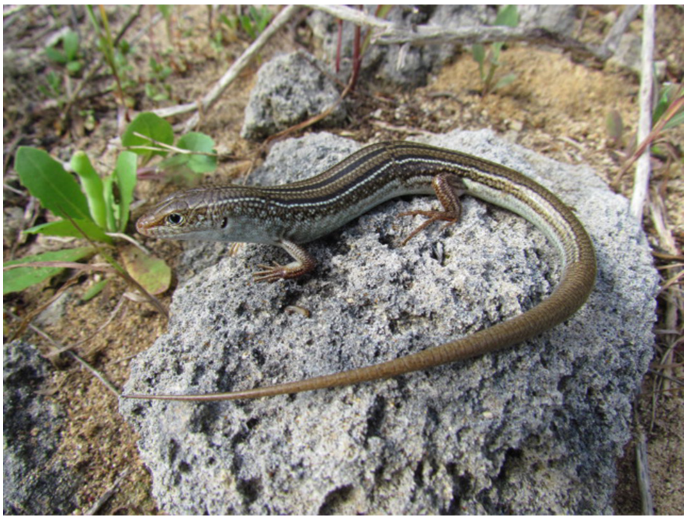

Plate 5. *Ctenotus fallens* (B. Maryan).

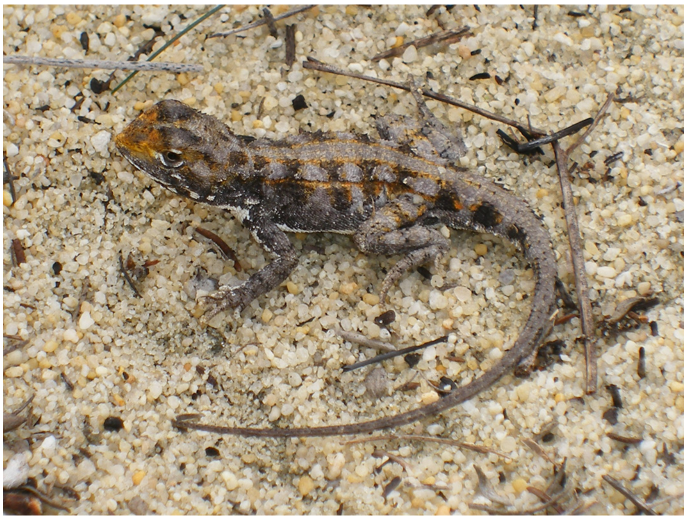

Plate 6. *Ctenophorus adelaidensis* (R. Browne-Cooper).

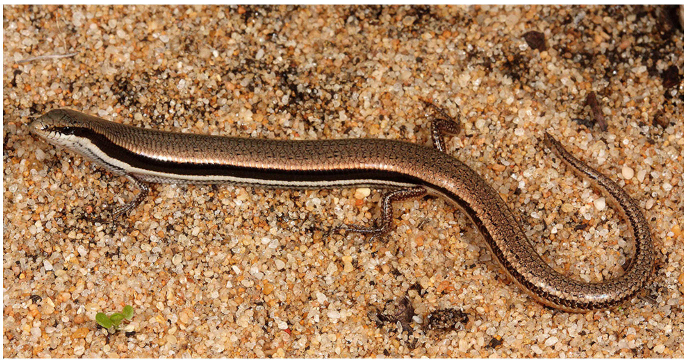

Plate 7. *Lerista elegans* (B. Maryan).

APPENDIX I

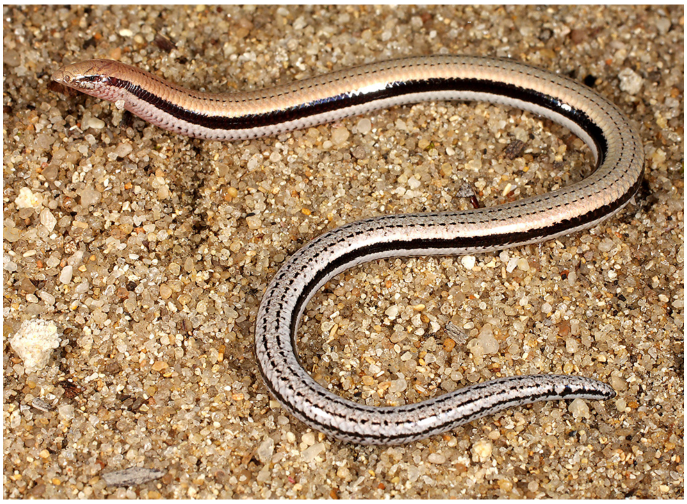

Plate 8. *Lerista praepedita* (.B. Maryan).

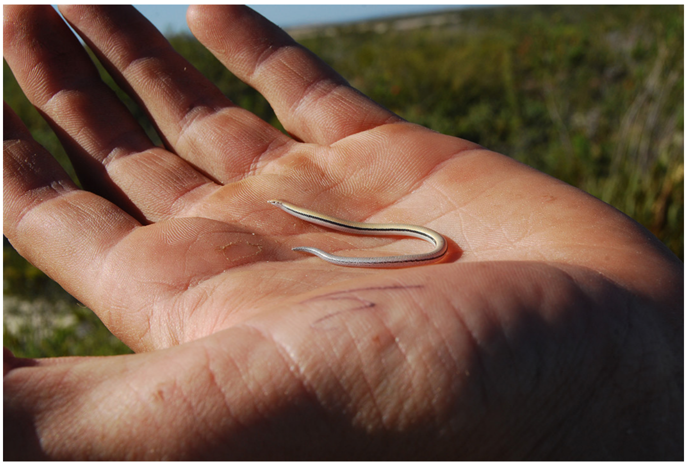

Plate 9. *Lerista praepedita* on a hand to give scale (S. Cherriman).

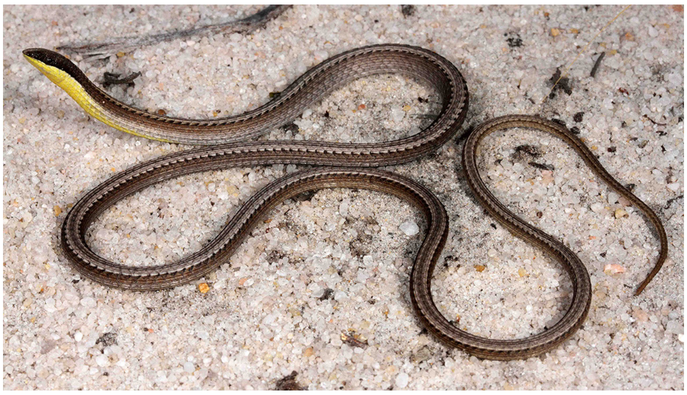

Plate 10. *Pletholax gracilis* (B. Maryan).

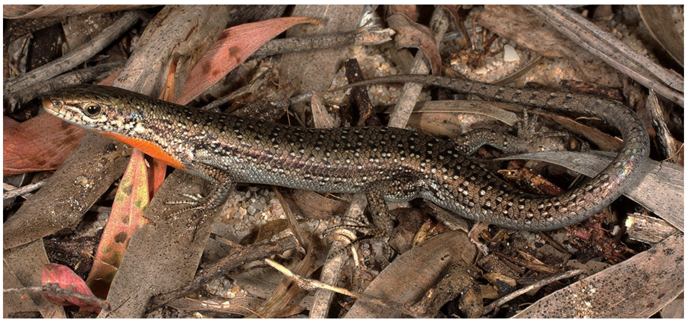

Plate 11. *Morethia obscura* breeding male (B. Maryan).